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**Cc:** Laidlaw, Tina[Laidlaw.Tina@epa.gov]  
**From:** Grant Weaver  
**Sent:** Thur 10/23/2014 2:46:25 PM  
**Subject:** optimizing municipal wastewater treatment facilities  
[2014 Montana Final Report.docx](#)  
[Sunderland Final Report - October 2014.docx](#)  
[Westfield report - April 2014.docx](#)

Bert,

Thinking you might be interested, I'm sending along a quick report on the wastewater optimization efforts I've been working on since we visited the East Helena, Montana facility in July of this year.

Following our visit, East Helena experimented with cycling aeration equipment; don't yet have any data, but staff tells me they are seeing big improvements.

Over the course of the summer, I visited 10 Montana plants.

A copy of my report to the DEQ is attached.

Secured a contract in Tennessee.

Will give a couple of training classes and provide a year's support to three POTWs, including 3-4 site visits.

Locked in treatment at the Palmer, MA POTW – a facility designed for chemical P removal but not nitrogen removal.

Effluent P remains in compliance.

Since July 2014 effluent total-N has averaged under 6 mg/L.

Principally because of reduced sludge disposal, O&M savings of \$50,000/yr are being realized at the 5.6 MGD (average daily flow) plant.

Provided technical support to the 0.5 MGD Sunderland, MA POTW.

So far inconsistent results, but improvements in effluent total-N have been realized.

A copy of my report is attached.

Begun preparing a conceptual design report for the 6.1 MGD (design) Westfield, MA POTW.

I'm working with staff to prepare long-term operations/design modifications - and - short-term/minimal cost modifications to demonstrate/confirm effectiveness of long-term design.

Earlier work in Westfield brought the facility into compliance with total-P limits while providing annual savings of over \$300,000.

Report attached.

Secured a contract with Montague, MA to support and document the past five years' POTW optimization efforts.

The 1.8 MGD (design) facility – not designed for nutrient removal – is providing inconsistent but periodically outstanding biological N&P removal.

A very high MLSS (mixed liquor suspended solids) concentration (8,000 mg/L) and strong aerobic, anoxic and fermentive habitats have reduced the MLVSS( mixed liquor volatile suspended solids concentration) from typical values of 75-80% to 20-25%.

Montague is feeding trucked-in waste sludge from over a dozen neighboring POTWs with combined flows that are three times that of Montague's while producing one-fourth the waste sludge of 5 years ago.

The net cost of treatment has been cut in one-half, producing an annual savings of over \$500,000.

I understand that Utah DEQ has contracted with a consulting firm to provide operational support to the state's 30 mechanical wastewater treatment plants.

Hopefully the effort will prove successful.

I remain very interested in working on optimization projects in Region 8 and elsewhere.

Please let me know how and where I might be of assistance.

Thank you!

Grant

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**Grant Weaver, PE and ABC Class IV wastewater operator**

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# **REPORT ON NUTRIENT OPTIMIZATION AT MONTANA MUNICIPAL WASTEWATER TREATMENT FACILITIES**

October 2014

## **OVERVIEW**

During the summer of 2014, The Water Planet Company supported the Montana Department of Environmental Quality (DEQ) effort to optimize nitrogen and phosphorus removal at the state's publicly-owned treatment works by providing two days of classroom training and making fifteen site visits to municipally-owned mechanical wastewater treatment facilities.

## **TRAINING**

A two day classroom training session was held by Grant Weaver of The Water Planet Company in Helena on June 17 & 18, 2014. Attendees included municipal wastewater treatment plant operators from Big Sky, Boulder, Bozeman, Conrad, Dillon, East Helena, Helena, Kalispell, Polson, Whitefish, and a private contract operations company; Montana DEQ staff; a Midwest Assistance Program technician, and engineers from several design firms. A complete listing of attendees is provided at the end of this report.

The first day of classroom training was a discussion of nutrient removal fundamentals with a focus on understanding, developing, monitoring, and adjusting conditions to provide optimal habitats for nitrogen and phosphorus removal. Information on the use of ORP (oxidation reduction potential) as a process control strategy was shared. Case studies were presented; examples of municipal wastewater treatment plants that – without facility upgrades – realized nitrogen and/or phosphorus removal by operating existing equipment differently. And the environmental relevance of nutrient removal and Montana's implementation strategy were discussed.

For the majority of the second day of classroom training participants discussed their individual treatment facilities. Those not presenting interacted with the presenters – asking questions and making suggestions. Grant Weaver moderated the discussions and provided a brief review of each plant's situation, focusing on opportunities for improved nutrient removal.

## **PLANT VISITS**

Eleven different municipal wastewater treatment plants were visited by The Water Planet Company's Grant Weaver. Four facilities were visited twice: Billings, East Helena, Helena, and Lolo. Montana DEQ and EPA Region 8 personnel were also on-site to provide technical support. The participants varied from facility to facility but included the following: Bill Bahr, Dave Frickey, Paul LaVigne, Jon Kenning, and John Arrigo (Montana DEQ) and Sadie Hoskie, Bert Garcia, Colleen Rathbone, and Tina Laidlaw (US Environmental Protection Agency).

A summary of the observations and recommendations for each treatment plant follows.

### ***Big Sky***

The Big Sky wastewater treatment facility serves the Big Sky ski resort and neighboring

residential communities. The aeration equipment at the Big Sky treatment plant is four to five times bigger than that of other similarly sized treatment facilities. On the day of the visit by DEQ's Bill Bahr and The Water Planet Company's Grant Weaver (August 21, 2014), the aeration diffusers were found to be torn. Plant superintendent Grant Burroughs had already ordered replacement equipment and was committed to replacing the diffusers once they arrived on site.

To reduce over-aeration and thereby reduce the shearing of the bacterial floc and improve nitrate-nitrogen removal, two major process changes were made during the plant visit. One. Three of the four 100 HP blowers were manually shut down so that only one of the 100 HP blowers would operate at any one time. Two. The air on/ air off settings were changed to increase the air off time.

Prior to the site visit an ORP meter was purchased and plant staff was provided with the following guidance. For optimal ammonia-nitrogen removal, the ideal end of react ORP is +100 to +150 mV (ammonia removal is optimized when it is consistently below 0.5 mg/L). For optimal nitrate-nitrogen removal, the ideal end of mix fill ORP is -100 mV (nitrate removal is optimized when it is 4-6 mg/L, or lower; nitrite should always be less than 0.5 mg/L).

A copy of the log sheet developed for the East Helena plant's use in monitoring field data results was provided and for the long-term, it was suggested that plant staff consider the purchase and installation of additional in-line probes such as ORP and TSS (total suspended solids).

A return visit during 2015 to provide follow-up technical support is recommended.

### ***Billings***

Two site visits were made. During the first visit (July 8, 2014) plant superintendent Susan Stanley gave DEQ's Bill Bahr and Grant Weaver of The Water Planet Company a comprehensive tour of the facility. The Billings plant is the largest in the State of Montana. It is a conventional activated sludge facility with the mechanical aeration equipment replaced by blowers and fine bubble diffusers. Modifications were made to the aeration tanks approximately ten years ago to provide anaerobic, anoxic and aerobic zones; but they aren't functioning as designed.

During the first visit, three concepts were discussed: (a) using the primary clarifiers differently, (b) using the gravity thickener as a fermenter and (b) cycling aeration equipment on and off to create alternating aerobic and anoxic conditions in the aeration tanks.

Prior to the second visit (August 19, 2014) plant staff experimented with cycling the aeration equipment. Due to extenuating circumstances, the experiment lasted only two days but encouraging results were achieved: ammonia removal remained unchanged but approximately one-third more nitrates were removed.

Notwithstanding the opportunities for nitrogen removal without capital investment, there is little interest in optimization and Billings is proceeding with a \$50 million facility upgrade.

### ***Bozeman***

Plant superintendent Herb Bartle provided DEQ's Bill Bahr and The Water Planet Company's Grant Weaver a tour of Bozeman's plant on July 7, 2014. The facility is operating well and plant staff is satisfied with current operating procedures.

## ***Columbia Falls***

Technical support was provided in 2013, but in response to a complete turnover in supervisory personnel a site visit was made by The Water Planet Company's Grant Weaver on August 27, 2014. Plant supervisor Gene Woods not only actively participated, both of his employees engaged in the discussion.

The difference in reporting ortho-phosphate "as  $\text{PO}_4$ " and "as P" were explained. To simplify data review, a data recording form was provided. It was suggested that plant staff use their spectrophotometer to measure the orthophosphate concentration in the both the final effluent and the outlet end of the anoxic tank. And, to use test strips to measure the ammonia, nitrite and nitrate in the final effluent and the outlet end of the anoxic tank. And, to write down ORP readings from the inline meter located in the anoxic tank. And, use the information for process control as discussed below.

### *Equalization Basin*

Because the phosphorus-rich sidestream flows go into the equalization basin, because the equalization basin flow is pumped into the bioreactor during periods of low flow (and therefore low BOD), because biological phosphorus removal requires a lot of BOD ... It was suggested to push more of the influent flow through the equalization basin. And, to provide better mixing of the tank contents. And, use the equalization basin more or less as originally intended; as plant staff have been doing since the 2013 site visit.

### *RAS pumping*

It was recommend that plant staff continue operating with as high of a return activated sludge (RAS) pump rate as the secondary clarifiers can take without adverse impact. And, to attempt to maintain a RAS pump rate that is approximately 100% of influent flow rate. Provided, that is, that the secondary clarifiers can accommodate the flow without adverse effect – and – further provided that DAF operations and sludge wasting are not adversely impacted.

### *Aeration Tank DO settings*

The following recommended changes to the aeration tank dissolved oxygen settings were made ... Zone 1: Increase the setting to 2.0 mg/L; in light of knowledge gained since last year's site visit, a higher upfront DO (dissolved oxygen) is better for biological phosphorus removal. Zone 2: Maintain the 1.5 mg/L DO setting, and increase it to 2.0 if necessary for ammonia removal. Zone 3: Maintain no aeration so as to minimize the amount of oxygen brought into the anoxic zone.

### *Phosphorus*

Optimize biological P removal and minimize chemical P removal as follows.

Try to get as high as possible of a  $\text{PO}_4\text{-P}$  concentration in the anoxic tank sample; something over 20 mg/L. Accomplish this by (a) making the tank ORP low (approximately -200 to -250 mV) and (b) feeding approximately 200-250 mg/L BOD into the anaerobic zone. If the pre-anoxic tank ORP is low (-200 to -250 mV) but the phosphorus release is minimal, experiment with adding increasingly larger quantities of waste sludge back into the headworks.

And, making sure that there is lots of DO at the front end of the aeration tank; 2.0 being a good target. Review data daily and routinely discuss with staff – and – make adjustments.

### Nitrogen

Maintain complete ammonia removal (effluent  $\text{NH}_4$  less than 0.5 mg/L) by keeping a high mixed liquor and high ORP in the latter half of the aeration tank. “High” being +100 mV or more.

Optimize nitrate removal by (a) adjusting the internal recycle pump rate and (b) ensuring that there is 200-250 mg/L of BOD entering the anaerobic zone. It’ll take some data gathering to figure out the optimal targets for the anoxic zone.

To find optimal conditions, correlate effluent Nitrate ( $\text{NO}_3$ ) with anoxic tank ORP. It is likely that the lowest effluent  $\text{NO}_3$  will occur when the anoxic tank ORP is somewhere in the range of -75 to -120 mV. When the optimal ORP range is found, adjust the internal recycle pump rates to provide an ORP reading that is +/- 40 mV of the optimal. When the ORP is too negative, increase the recycle pump rate. When the ORP is getting too close to zero, reduce the recycle pump rate.

A return visit during 2015 to provide follow-up technical support is recommended.

### **Conrad**

DEQ’s Dave Frickey and Grant Weaver of The Water Planet Company visited operator Keith Thaut at the facility on August 26, 2014. Following a two-day training class in 2012, Keith altered the plant’s treatment process by cycling aeration equipment on and off. Doing so reduced effluent nitrogen by 82% from 26 mg/L to under 5 mg/L.

Turbidity data were not available, but a visual observation puts it extremely low, around 1 NTU. Conrad’s is among the clearest effluents ever seen by the team.

The current mode of operation is as follows.

During the summer Conrad operates the aeration tank so that it receives air for 3 hours followed by 2 hours without any aeration. During the winter Conrad operates the aeration tank so that it receives air for 2 hours followed by 1½ hours without any aeration.

The sludge digester receives the same amount of aeration as the aeration tanks – plus, however long the two floating jet aerators are operated. To improve biological phosphorus removal it was suggested that the jet aerators operate only when sludge is wasted to the drying beds, if then.

Technical support on using the plant’s colorimeter to perform ortho-phosphate testing (without the need for the digestion required for total-P testing) was provided. The Hach TNT vials can, for the most part, be used for either “reactive” or “total” phosphate. And, the following primer on understanding phosphorus test results was provided.

For purposes of wastewater treatment, there are two kinds of phosphorus: (1) the phosphorus that is dissolved in the water and (2) the phosphorus that is part of the MLSS (mixed liquor suspended solids) and therefore the effluent TSS. With the low effluent TSS produced at the Conrad facility (0-5 mg/L) the amount of phosphorus in the TSS is likely 0.05-0.25; the rest of the phosphorus being soluble phosphorus. Which therefore means that all but a very small amount of the effluent phosphorus (less than 0.25 mg/L) is ortho-phosphate, the “reactive” phosphate that the TNT test method provides without digestion.

Which means... Plants such as Conrad can use the TNT test to determine the reactive phosphate – provided they record the results as  $\text{PO}_4 - \text{P}$ , and not  $\text{PO}_4$ . Most spectrophotometers have three ways of reporting phosphate, generally with “ $\text{PO}_4$ ” as the default. To get usable results it is important to toggle through the options and change the reading from “ $\text{PO}_4$ ” to “ $\text{PO}_4 - \text{P}$ .”

To optimize phosphorus removal, it was suggested that Conrad continue to return sludge from their sludge digestion tank. It was recommended that instead of continuously aerating the sludge tank that it instead receive little to no aeration.

A substantial reduction in dewatered sludge production was experienced by Conrad during the summer of 2014. It was explained that this occurred because bacteria are breaking apart and being consumed in the two environments: aeration tank and digester. And, that much of the carbon is being broken down to carbon dioxide ( $\text{CO}_2$ ) and released into the atmosphere instead of being removed as sludge.

Conrad was advised that as they experiment with the amount of sludge pumped from the digester back into the aeration tank, they will need to adjust the amount of sludge wasted. For example, as the amount of sludge pumped into the aeration tank is increased, it will be necessary to also increase the amount of sludge wasted back into the digester. And, visa-versa: as the amount of sludge pumped into the aeration tank is reduced it'll be necessary to reduce the amount of sludge wasting. The more sludge pumped back from the sludge digester, the more VFAs (volatile fatty acids) and bio-P bugs (“PAOs” – phosphate accumulating organisms) that are returned to the aeration tank, and the better the phosphorus removal. And, the less sludge that will have to be pumped onto the drying beds. However, the more sludge pumped into the aeration tank, the greater the loading on the clarifier(s). Caution was advised.

### ***Dillon***

On August 20, 2014 Dillon Water Supervisor Jason Johnson led the following on a tour of Dillon's newly constructed mechanical treatment plant: Jon Kenning, John Arrigo, Paul LaVigne and Bill Bahr of DEQ and Grant Weaver of The Water Planet Company. Given that the facility is so new and the plant staff unaccustomed to operating a mechanical treatment facility, the technical support team recommended that plant staff concentrate on maintaining ammonia removal during the winter of 2014/2015.

In order to maintain a target ammonia concentration of 0.5 mg/L or lower, the technical support team recommended that staff measure ammonia in-house three days a week, daily if at all possible. To simplify monitoring it was recommended that test strips be used.

As a process control tool for conventional treatment it was recommended that an inline TSS (total suspended solids) probe be installed alongside the existing DO (dissolved oxygen) probe. And, that staff attend training classes and utilize free online resources to learn more about mechanical wastewater treatment facilities.

A return visit during 2015 to provide technical support with nitrate-nitrogen removal and biological phosphorus removal is recommended.

### ***East Helena***

Two visits were made to the East Helena wastewater treatment facility. On July 16, 2014 East Helena's Steve Leitzke led DEQ's Bill Bahr and Dave Frickey on a tour of the treatment facility.

On August 25, 2014 four EPA Region 8 officials (Sadie Hoskie, Bert Garcia, Colleen Rathbone, and Tina Laidlaw), DEQ staff (Bill Bahr, Dave Frickey, and Paul LaVigne), and Grant Weaver of The Water Planet Company met with East Helena's Steve Leitzke. A significant amount of data was provided.

The treatment facility is effectively removing ammonia but a considerable amount of nitrate remains in the effluent. The team recommended cycling the aeration blower on and off in order to create anoxic conditions suited to nitrate removal. So that the staff could become comfortable with operating the aeration zone without continuous aeration, it was recommended that the aeration equipment be manually turned off for an hour per day for a period of a week. And, to then manually turn it off for two hours daily for a second week. After which, assuming no problems arise, to install a timer so that the blower can be programmed to automatically cycle on and off. During the first visit plant staff was receptive to the concept but perhaps due to the demands of dealing with recent personnel changes had not done any experimenting.

A return visit during 2015 to provide follow-up technical support is recommended.

### ***Helena***

Two visits were made: July 16, 2014 and August 25, 2014. DEQ's Bill Bahr and Dave Frickey attended along with Grant Weaver of The Water Planet Company. The same team made technical support visits in 2012 and 2013. Mark Fitzwater and the entire Helena staff is fully engaged in the optimization process, notwithstanding some setbacks during the winter of 2013/2014 when the system was operated with one-half of the on-line aeration of previous years.

Nitrogen removal was the focus of the prior years. During 2014, with both aeration tanks (bioreactors) back in service, staff is focusing on biological phosphorus removal. Options for scouring the contents of the one in-service primary clarifier were discussed during the initial site visit and implemented before the second. Over the interim, effluent phosphorus dropped in half while nitrogen removal remained quite good.

Based on these results, the following operating strategy was agreed upon.

#### **Target MLSS concentration with two bio-reactors in service**

During the summer maintain a mixed liquor suspended solids (MLSS) concentration of 3500 mg/L. During the winter increase the MLSS to 4000 mg/L and, if the plant responds to the increase well, perhaps higher.

#### **Process Control**

Maintain the Mixed Liquor Recycle (MLR) rate as-is. Maintain the RAS rate as-is, or as needed to optimize clarifier performance. Keep the aeration DO settings as-is: 3.0 mg/L in the first aeration zone, 2.0 mg/L in the second, and 1.0 mg/L in the third.

As long as odors and/or freezing aren't an issue, continue using plant water to flush solids (and solubilize BOD) in the primary clarifier. During the work day: Pump to waste for 2 minutes and turn the primary waste pumps off for 10 minutes. No flush water during the day. After hours: Run the flush water for 5 minutes per hour. No wasting after hours.

#### **Maintenance**

Increase the frequency of staff cleaning of the in-line DO probes to twice per month.

### Near-term Projects

In the bio-reactors, see if there isn't a way to either raise the water elevation so scum flows over the top of the scum trough and into the secondary clarifiers - or - lower the water level so the float goes under the scum baffles and into the clarifiers. If not, seriously consider removing the scum troughs.

### Future Projects

For improved bio-P removal, extend the MLR outlet 20-30 feet into the anoxic/anaerobic basin. In the headworks, install fine screen and remove one or more sections of primary scum baffle to minimize odors in the primary clarifier. Cover primary clarifier(s) for odor control.

Because the plant staff is so engaged and so responsive to technical support, a return visit during 2015 to provide follow-up technical support is recommended.

### ***Kalispell***

Plant superintendent Curt Konecky provided DEQ's Paul LaVigne and The Water Planet Company's Grant Weaver a tour of Kalispell's nationally regarded wastewater treatment facility on July 14, 2014. The facility operates extremely well.

Upon receipt of a protocol for determining whether additional retention time in anoxic conditions will improve nitrate removal was received by email, plant staff performed laboratory testing and found little opportunity.

The option of utilizing incorporating one additional treatment cell for anoxic treatment was recommended by the technical team. As of the writing of this report, results were not available.

### ***Lewistown***

The Lewistown wastewater treatment plant produces a high quality effluent notwithstanding frequent equipment breakdowns. On July 9, 2014 DEQ's Dave Frickey and Grant Weaver of The Water Planet Company visited the facility. Visits were also made in 2013. The visits are providing supervisor Holly Phelps and staff with motivation to improve odor control and be more attentive to plant operations and maintenance. For these reasons, a return visit during 2015 to provide follow-up technical support is recommended.

### ***Lolo***

Two visits were made. On July 15, 2014 DEQ's Bill Bahr and Dave Frickey along with Grant Weaver of The Water Planet Company visited with chief operator Jasen Neese and HDR Engineer, Sean Everett. A follow-up visit was made by Grant Weaver on August 28, 2014. Between visits, the amount of aeration in the first of three aeration tank cells was reduced to a minimum. Doing so reduced phosphorus by 1-2 mg/L from 4-5 mg/L to 3 mg/L; one sample was 0.25 mg/L!

Total-N was typically around 25-30 mg/L. The ammonia concentration was less than 0.5 mg/L, but the nitrate was 20-25 mg/L. Nitrate dropped to 17 mg/L, reducing the total-nitrogen by over 5 mg/L.

At the recommendation of the technical support team, an ORP probe was purchased. An initial set of readings provided encouraging information: -50 mV in the first cell, +130 in the second, and +220 in the third. The plant has very limited control (ball valves on a common aeration header), but the following ORP targets were discussed: below -100 mV in the first cell, +100 to +150 mV in the second and third cells.

For the long-term the technical team agreed with the plant operator's idea of turning the air off completely in the first aeration zone and mixing the contents with some kind of mixing device; something that the operator agreed to research.

To control bacterial foam in the first aeration cell, it was recommended that the operator spray daily with a hand-pump pesticide sprayer containing 1/3 store bleach and 2/3 water.

The team provided information on free resource materials including on-line documents and webinars.

A return visit during 2015 to provide follow-up technical support is recommended.

**Advanced Wastewater Training with/ Grant Weaver**  
Helena, Montana  
June 17&18, 2014

<u><i>Name</i></u>	<u><i>System</i></u>
Keith Thaut	City of Conrad
Grant Burroughs	Big Sky Water & Sewer District
Greg Acton	City of Whitefish
Jesse Benbrook	City of Whitefish
John Wilson	City of Whitefish
Scott Anderson	Eng for City of Whitefish
Adam _____	Eng for City of Whitefish
Curtis Konecky	City of Kalispell
Del Phipps	City of Kalispell
John McDunn	DEQ Eng
Brandon Packer	City of Polson
Earle Cole Davis	City of Polson
Rob Dumke	City of Dillon
Stanley A. Roder	City of Dillon
Fred Irby	City of Helena
Mark Fitzwater	City of Helena
Charles T. Patera	City of Helena
Jeff Brown	City of Helena
Mark DeWald	City of Bozeman
John Boie	City of East Helena
Dennis Wortman	City of Boulder
Alden Beard	Private Engineer
Michele Marsh	DEQ Eng
Patrick Johnson	DEQ Eng
Erinn Zindt	MAP
Pete Boettcher	DEQ WPB Env Spec
Tommy Griffiths	DEQ WPB Env Spec
Dan Emter	City of Livingston
Kate Miller	Private Engineer
Ed Janney	Private Engineer
Lee Wolfe	Contract Operator

# REPORT on Nutrient Removal at the Sunderland Wastewater Treatment Plant

October 2014

## **Background**

Concerns about nitrogen levels in Long Island Sound and elsewhere across New England are affecting discharges from facilities such as the Sunderland wastewater treatment plant. Facilities are being asked to optimize nutrient removal. Permit limits will surely follow.

Optimization work performed at the municipal wastewater treatment facilities serving Amherst, Westfield, Montague, and Palmer has resulting in impressive reductions in the discharge nitrogen and phosphorus at reduced cost. The efforts have not only eliminated the need for tens of millions of dollars of facility upgrades, the facilities listed have reduced the cost of wastewater treatment by nearly \$1,000,000 annually.

Beginning mid-2014, Warner Brothers' staff began experimenting with process changes. The mixed liquor concentration with successful results: sludge production has been reduced by approximately 50% from 8-10 loads per month to 3-4 loads per month; providing ongoing annual savings. Aeration equipment was cycled on and off in an effort to improve total-nitrogen removal with mixed success.

In light of the promising results, Warner Brothers, the operator of the Sunderland wastewater treatment facility recommended the employment of The Water Planet Company to work with Warner Brothers staff to optimize nutrient removal.

## **Project Overview**

Three visits to the Sunderland wastewater treatment plant were made (8/6/14, 9/16/14, and 10/15/14). Between visits, plant operations were discussed via email and telephone. During the first visit, changes were made to the aeration system: the air on and air off cycle times were extended such that the air was on for 3 hours and off for 1 hour and later to the 4 hours on and 45 minutes off. New laboratory equipment costing approximately \$750 was purchased before the second visit in order to (a) more accurately measure ammonia-nitrogen, nitrate-nitrogen, and nitrite-nitrogen and (b) provide data on ORP, oxidation reduction potential.

Data were reviewed during the subsequent visits and process adjustments were made in an effort to optimize nitrogen removal. The project focus was entirely nitrogen removal; no efforts were made to optimize phosphorus removal (more on this at the conclusion of the report).

## **Results**

Optimization efforts provided immediate, positive results. Ammonia-nitrogen was reduced by 80% from 10.4 mg/L to 2.1 mg/L and total-nitrogen was reduced by 50% from 15.0 mg/L to 7.3 mg/L\*. However, as shown in the table that follows, nitrogen values spiked after Labor Day,

returning to nearly the same levels as before the optimization effort.

**Table 1: Sunderland In-house\* Nitrogen Testing (2014)**

	<u>Ammonia*</u>	<u>total-N*</u>
July 1 - August 5	10.4	15.0
August 6 - August 31	2.1	7.3
September 1 - October 15	8.2	13.7

### **Observations**

*Nitrogen Removal.* By cycling existing aeration equipment, the Sunderland wastewater treatment facility should be capable of meeting most any nitrogen limit imposed by Federal and State regulatory agencies during summer months. A significant increase in effluent nitrogen occurred during the Labor Day weekend. It is not known why this occurred but it is believed that the student population attending Sunderland Elementary School and – perhaps more significantly – the students who seasonally reside in the Sunderland sewer service area and attend the University of Massachusetts create an increased loading on the wastewater treatment plant which results in a loss of nitrogen removal efficiency. Additional monitoring over a longer period of time is required to confirm cause and effect.

Throughout the study period plant staff operated the treatment plant at a sufficiently high mixed liquor concentration (3500 mg/L), hydraulic retention time (24+ hours), and ORP (100+ mV) to support ammonia removal. The dissolved oxygen concentration (DO) however was at times very low (less than 0.5 mg/L). Equipment limitations – specifically the amperage limit of the variable frequency drive controlling mechanical aeration – restrict staff's ability to supply all of the oxygen otherwise available.

*Phosphorus Removal.* No effort was made to implement biological phosphorus removal. However, the facility is well equipped to do so. A protocol for a full-scale trial is described in the section that follows.

### **Recommendations**

*General.* Continue collecting, monitoring and recording in-house data. Continue monitoring ORP. Continue monitoring pH and alkalinity. Continue to increase plant knowledge and optimization skills by observing treatment processes and informally correlating ORP, DO, alkalinity and nitrogen data. Supplement in-house knowledge by continuing to actively search for resource materials.

*Nitrogen Removal.* Focus on optimizing ammonia removal first and nitrogen removal second by ensuring sufficient oxygen in the aeration tank during the air on cycles. Consider replacing the aerator VFD to one with a higher amperage capacity; one more suitable for the on-off cycling necessary for optimal nitrogen removal. Maintain high mixed liquor concentration so that sufficient nitrifying bacteria are available for (a) ammonia removal and (b) a DO/ORP drop

during the air off cycle sufficient to support nitrate removal.

*Phosphorus Removal.* A decision was made to focus exclusively on nitrogen removal at the onset of the optimization effort. Biological phosphorus removal however can be achieved by recycling sludge from the sludge holding tank to the aeration tank.

The time to experiment with biological phosphorus removal would be next summer after the plant is effectively removing ammonia to 1.0 mg/L or less. To begin the experiment ten percent of the waste sludge should be returned to the aeration tank daily; doing so keeps the bio-P bacteria in circulation. A corresponding increase in sludge wasting needs to occur to maintain the desired mixed liquor concentration. For further information on biological phosphorus removal, please refer to the attached, supplemental page.

### **Conclusions**

There are two barriers to the Sunderland wastewater treatment plant achieving year-around nitrogen removal.

The first impediment is the effects felt immediately following Labor Day, presumably an annual event. A better understanding of what occurred is needed. Presumably, there is an annual increase in flow and loading; an increase that temporarily overwhelms the facility's ability to biologically remove nitrogen. The cause needs to be better understood (i.e., influent BOD, total-N, and flow – before and after Labor Day). After which, an action plan can be developed.

The second impediment is that of aeration equipment. It appears that, at times, operating at 88% the existing mechanical aerator is not capable of providing sufficient oxygen to support complete ammonia removal. Replacing the existing VFD with one that will allow the aerator to cycle on at 100% without tripping out may be sufficient.

\*Note: The data are all in-house testing using non-EPA approved procedures. The total-N values are estimated by totaling ammonia, nitrite and nitrate and adding an assumed 2.0 mg/L organic-nitrogen value.

## ENHANCED BIOLOGICAL PHOSPHORUS REMOVAL

GRANT WEAVER, PE & WASTEWATER OPERATOR  
PRESIDENT, THE WATER PLANET COMPANY

Phosphorus is an essential nutrient in the growth of all living things. During conventional wastewater treatment, some 2 mg/L of phosphorus is typically removed from the wastestream and converted to bacterial mass. By weight, bacteria are approximately 1.5 percent phosphorus. Meaning, for every dry ton of waste sludge, 30 pounds of phosphorus is biologically removed from wastewater.

“Enhanced” biological phosphorus removal increases the dry weight component of phosphorus to as high as five percent, maybe more. Wastewater professionals who understand the process can quadruple phosphorus removal without the use of chemicals.

Enhanced biological phosphorus removal is a two step process: a period of anaerobic treatment (zero oxygen), followed by highly aerobic treatment at neutral or higher pH. Volatile fatty acids (VFAs) drive the process. VFAs are produced in anaerobic conditions.

The anaerobic treatment cannot be a digester; VFAs are destroyed during anaerobic digestion, they are converted to methane gas. In fact, the undesirable “acid” in the acid/alkalinity ratio that is used to monitor the effectiveness of anaerobic digesters is VFA. For enhanced biological phosphorus removal, it is important to ferment and not completely digest waste so that (i) a supply of volatile fatty acids are created in advance of an aerobic zone and (ii) a family of bacteria called PAOs, phosphate-accumulating organisms, take in the VFAs. The wastewater needs to contain approximately 25 times as much BOD as phosphorus in order to support biological phosphorus removal. During fermentation, the bacteria (PAOs) temporarily release a lot of the phosphorus stored within their cells into the wastestream.

When the PAO bacteria enter an aeration tank with high a high dissolved oxygen content and neutral pH (both conditions are very important for biological phosphorus removal) they use the VFAs as an energy source and take in all but 0.05 mg/L (or less) of the soluble ortho-phosphorus. The phosphorus is removed with the bacteria as waste sludge. There is a temporary increase in phosphorus concentration in anaerobic tanks.

Municipal wastewater treatment plant staff can create volatile fatty acids in any number of ways. VFAs can also be imported; for example with septage.

The three textbook ways of creating VFAs are: (i) in a mainstream anaerobic tank located ahead of aeration, (ii) in a primary sludge fermenter, and (iii) in a return sludge selector. Once established, the biological process needs little to no attention. Simply allow moderate to high BOD to remain anaerobic for a period of an hour or longer. Aerobic digesters can be converted to fermenters by turning the air off. Similarly, sludge holding tanks, gravity thickeners, and other zones of zero oxygen and high-BOD can be made into fermenters.

A well operating biological phosphorus removing facility can reduce effluent phosphorus to 0.2 mg/L. To achieve this level of treatment, the effluent TSS (total suspended solids) concentration must be very low. Each mg/L of effluent TSS contains approximately 0.05 mg/L of phosphorus. To meet an effluent limit of 0.5 mg/L or less, effluent TSS and effluent ortho-P must be closely monitored and controlled.

## Phosphorus Removal at the Westfield, Massachusetts Wastewater Treatment Facility April 2014

Changes in the day-to-day operations are providing annual savings of \$367,000 at the 6.1 MGD Westfield wastewater treatment plant. Westfield invested less than \$50,000 in equipment and consulting services and approximately 150 hours of in-hour labor. A summary of the cost savings follows.

	Old Permit	New Permit			
	Chemical P-Removal	Chemical P-Removal	Biological and Chemical P-Removal		
	Annual Cost	Annual Cost	Annual Cost	Savings vs. Chemical	Savings vs. Old Permit
<b>Chemical Costs</b>	\$265,000	\$370,000	\$174,000	<b>\$196,000</b>	<b>\$91,000</b>
<b>Sludge Disposal Costs</b>	\$682,000	\$672,000	\$498,000	<b>\$174,000</b>	<b>\$184,000</b>
<b>Electrical Costs</b>	\$409,000	\$357,000	\$360,000	<b>-\$3,000</b>	<b>\$49,000</b>
<b>TOTAL</b>	<b>\$1,356,000</b>	<b>\$1,399,000</b>	<b>\$1,032,000</b>	<b>\$367,000</b>	<b>\$324,000</b>

As the following table illustrates, by implementing biological phosphorus removal to supplement chemical phosphorus removal, the Westfield wastewater treatment plant is not only operating at lower cost, the process changes have made the facility compliant with its new total-phosphorus effluent limits.

	Flow (MGD)	effluent concentration (mg/L)			
		total-P	total-N	TSS	BOD
<b>2011: Sodium aluminate</b>					
winter: no limit	3.7	<b>2.9</b>	15.5	8	12
summer: 1.0 mg/L total-P	3.5	<b>0.2</b>	9.9	6	4
<b>2012: PAC</b>					
winter: 1.0 mg/L total-P	3.5	<b>4.0</b>	16.5	8	13
summer: 0.46 mg/L total-P	2.5	<b>0.5</b>	11.4	4	3
<b>2013: experimental</b>					
winter: 1.0 mg/L total-P					
summer: 0.46 mg/L total-P	3.1	<b>1.1</b>	8.3	7	8
<b>2014: bio-P and Sodium aluminate</b>					
winter: 1.0 mg/L total-P	3.0	<b>0.5</b>	13.1	12	12
summer: 0.46 mg/L total-P					

## **Background**

Westfield's discharge permit limits changed November 2011. The seasonal limit became a year round limit. Westfield is now required to meet an effluent total-P limit of 0.46 mg/L during the months April to October and 1.0 mg/L the rest of the year (November through March). Prior to the change, Westfield needed to meet a seasonal (June to October) limit of 1.0 mg/L; there was no wintertime limit.

Westfield maintained compliance with its old permit by using sodium aluminate; approximately 325 gallons per day were added during the summer months, none was added during the winter months. With year round limits Westfield changed from sodium aluminate to PAC (poly-aluminum chloride). Pure sodium aluminate freezes at 10 degrees F (-10°C); however, some solutions freeze at temperatures as high as 32°F (0°C). Epic 58, the PAC product that was used at Westfield, freezes at 10 degrees F (-10°C).

Initially, PAC provided the same results at approximately the same dose as sodium aluminate and Westfield was able to maintain permit compliance. However, during the winter of 2012-2013, Westfield was unable to maintain compliance, even at very high dosages of PAC (500 gallons per day). To make matters worse, solids were not settling and Westfield was having difficulty meeting its effluent TSS limit.

In an effort to achieve compliance, Westfield staff took a number of appropriate actions. Brian Tanner of The Holland Company, the PAC chemical supplier, performed jar tests; mixed liquor samples were sent to Dr. Michael Richard for microbiological analyses; and microbiologist Michael Gerardi visited the facility to provide guidance. In May of 2013, Westfield contacted Grant Weaver of The Water Planet Company for additional support.

## **Experimentation**

Believing that the problem might lie with the PAC product, Westfield ran the three parallel treatment trains with three different dosages: sodium aluminate was added to train 1, PAC to train 2, and no chemicals were applied to train 3. To promote biological phosphorus removal in train 3, two actions were taken: (1) a fermentation zone was created by turning off the air in one-third of the tank and (2) the use of chlorine as an odor control agent in the sludge storage tank was discontinued, a pump was installed in the sludge holding tank, and approximately 8600 gallons per day of waste sludge were pumped midway into the air-off zone.

After one month of experimentation, with no chemicals at all, train 3 reduced phosphorus from 3 mg/L to 0.5 mg/L, almost enough to meet the summertime permit limit. The experiment also demonstrated that sodium aluminate is twice as effective as PAC. Staff decided to discontinue PAC in favor of sodium aluminate. Heat tape was installed on the chemical feed piping and the chemical feed pipes were covered with insulation to prevent freezing. Results from the May 2013 experimentation are shown on the following page.

Encouraged by the results observed in train 3, process changes were made in an effort to optimize biological phosphorus removal throughout the plant and thereby reduce the amount of

chemicals required. The air into the first one-third of all three aeration trains was shut off to create fermentation zones for biological phosphorus removal.

To keep the contents in the non-aerated tanks mixed, Westfield staff creatively manufactured their own “big bubble” mixing system by modifying the existing fine bubble diffusers. Over ninety-percent of the fine bubble ports in the anoxic zone of each of the three treatment trains were sealed to prevent any escape of air. The rubber membranes covering the remaining 5-10% of the diffusers were cut to allow large bubbles of air to escape. The bubbles keep the contents mixed without transferring much oxygen into the tanks. The diffusers in the swing zones were not modified; the contents of these zones are mixed by keeping the air headers cracked to allow some air and daily fully opening the air headers for approximately 15 minutes.

	Chemical Dose (GPD)		Sludge (GPD)	ortho-P (mg/L)
	PAC	NaAl		
<b>Train 1: Sodium aluminate</b>	0	75	0	0.32
<b>Train 2: PAC</b>	170	0	0	0.20
<b>Train 3: No chemicals</b>	0	0	8,600	0.50

An in-line orthophosphate analyzer was installed to provide around-the-clock monitoring of the soluble phosphorus concentration in the final effluent. Data from the analyzer is sent to plant's SCADA system. The around-the-clock data has proven invaluable in diagnosing and controlling phosphorus removal.

Westfield staff purchased a portable ORP meter to monitor conditions throughout the plant. And, to provide better oxygen control in train 3, the dissolved oxygen (DO) probe used to control the aeration tank oxygen level was relocated from the beginning of the second pass to the end of the third pass.

## Science

In order to provide enhanced biological phosphorus removal, Westfield created the two habitats necessary for biological phosphorus removal: a fermentation zone followed by a highly aerobic zone.

In the fermentation zone at an ORP (oxidation reduction potential) reading of -250 mV, two biological processes occur. One family of bacteria creates highly digestible volatile fatty acids (VFAs) by metabolizing the long-chain carbohydrates contained in wastewater. Another family of bacteria – phosphate accumulating organisms (PAOs) – take in the VFAs as an energy source.

In the aerobic zone, the PAOs use the energy they acquired in the fermentation zone as a food source. When supplied with oxygen, they grow; and, remove soluble phosphorous (ortho-phosphate) from the wastewater.

Using existing equipment, Westfield created attractive habitats for these bacterial actions in

order to remove phosphorus with fewer chemicals. Using the portable ORP meter, Westfield treatment plant personnel monitor and control the environmental habitats. Using the in-line ortho-phosphate analyzer, staff monitor and control effluent phosphorus concentration.

	total Phosphorus limit (mg/L)	Phosphorus Removal				pH buffer		Total
		Sodium aluminate		PAC		Caustic soda		
		GPD	\$/YR	GPD	\$/YR	GPD	\$/YR	
2011: seasonal P removal only			\$164,000		\$0		\$101,000	\$265,000
winter (Jan-May & Nov-Dec)	No Limit	0	\$0	0	\$0	330	\$43,000	
summer (June-October)	1.0	327	\$164,000	0	\$0	320	\$58,000	
2012: first year of year-round P removal			\$0		\$265,000		\$105,000	\$370,000
winter (Jan-Mar & Nov-Dec)	1.0	0	\$0	362	\$108,000	364	\$47,000	
summer (April-October)	0.46	0	\$0	372	\$157,000	317	\$58,000	
2013: second year of year-round P removal			\$24,000		\$135,000		\$123,000	\$282,000
winter (Jan-Mar & Nov-Dec)	1.0	51	\$18,000	246	\$73,000	323	\$42,000	
summer (April-October)	0.46	12	\$6,000	146	\$62,000	440	\$81,000	
2014: year to date			\$111,000		\$0		\$63,000	\$174,000
winter (Jan-Mar & Nov-Dec)	1.0	134	\$48,000	0	\$0	200	\$26,000	
summer (April-October)	0.46	125	\$63,000	0	\$0	200	\$37,000	

## Results

By combining biological phosphorus removal with chemical phosphorus removal, Westfield is now meeting its summertime permit limit of 0.46 mg/L total-P with only 125 gallons per day of sodium aluminate. Prior to the implementation of biological phosphorus removal, Westfield was using twice as much. At a cost of \$2.37/gallon, Westfield is providing more sustainable wastewater treatment and saving over \$420 per day on phosphorus removing chemicals year round.

## Other Benefits

In optimizing phosphorus removal, a number of other benefits were realized, as discussed below.

*Caustic Soda.* In addition to the \$154,000/year reduction in PAC/sodium aluminate expenses, the amount of caustic soda has been reduced by \$42,000/year. There are two reasons for the reduction in caustic soda. One, poly-aluminum chloride (PAC) is a weak acid while sodium aluminate is a base containing approximately the same alkalinity as the 25% caustic soda that Westfield uses for pH control. Substituting sodium aluminate for PAC reduces the need to buffer the pH with caustic soda. Two, the steps taken to optimize biological phosphorus removal also improved total-nitrogen removal by enhancing the habitat for converting nitrate-nitrogen to nitrogen gas, an alkalinity producing chemical reaction.

*Sludge disposal.* Another side benefit of biological phosphorus removal is sludge reduction. The volatile fatty acids (VFAs) contained in the waste sludge that is recycled from the holding tank

into train 3 for bio-P removal are created by the partial degradation of the sludge. The degradation process is continued in the fermentation tank and subsequent aeration tank, resulting in, a 26% reduction. Now, one dry ton less sludge is removed from the facility daily!

	Sludge Removed (dry pounds)		Annual Cost
	lbs/day	lbs/yr	
<b>2011:</b> seasonal P removal only	<b>7,724</b>	<b>2,819,132</b>	<b>\$682,000</b>
<b>2012:</b> first year of year-round P removal	<b>7,608</b>	<b>2,777,008</b>	<b>\$672,000</b>
<b>2013:</b> second year of year-round P removal	<b>5,848</b>	<b>2,134,529</b>	<b>\$517,000</b>
<b>2014:</b> January through March	<b>5,426</b>	<b>488,348</b>	<b>\$479,000</b>

*Electricity.* Another factor is electricity. With one-third of the aeration tank capacity operated in an air-OFF mode, the oxygen requirement is reduced. The majority of the electrical requirement for most wastewater treatment plants is for aeration equipment.

As shown in the table below, since implementing biological phosphorus removal, Westfield has seen a slight reduction in electrical consumption, something on the order of 3-8%, and annual savings of up to \$49,000/year.

	Electric (KWH)	Electric (\$/yr)
Seasonal P-removal only: May '11 - Apr '12	2,970,900	\$409,000
Chemical P-removal: May '12 - Apr '13	2,803,800	\$357,000
Bio & Chemical P-Removal: May '13 - Apr '14	2,716,500	\$360,000

## Next

A number of temporary measures have been employed to realize these savings – example, sludge pumping to train 3. By reinvesting some of the savings in permanent changes and by improving monitoring equipment so that Westfield staff can better track treatment performance, Westfield will realize ongoing savings for many years to come.

Although reduced by nearly \$200,000 per year, Westfield's chemical costs are still high. With a better means of providing fermentation for biological phosphorus removal and with more in-line monitoring equipment, the \$174,000 annual chemical expenditure can be further reduced. It is therefore in the community's best interest to develop a strategy to (a) make the temporary fixes

permanent and (b) consider additional, long-term improvements that will provide the most cost-effective means of meeting new permit limits (e.g., nitrogen) at current and design flows.